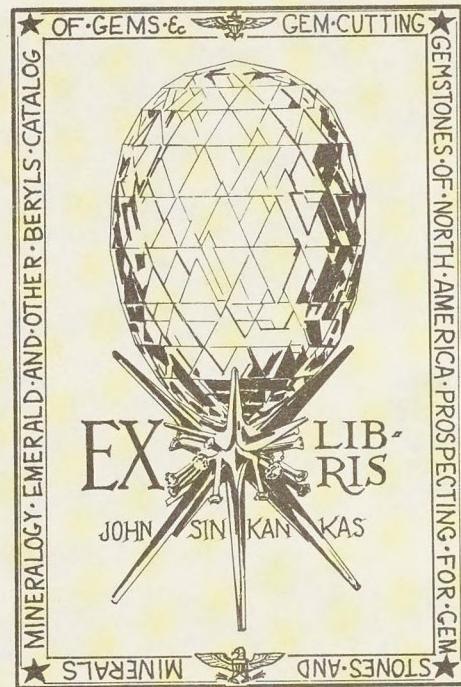


CHART
SHOWING
THE CHEMICAL RELATIONSHIPS
IN THE MINERAL KINGDOM

PALMER COSSLETT PUTNAM, M.S.



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A CHART SHOWING THE CHEMICAL RELATIONSHIPS IN THE MINERAL KINGDOM

BY
PALMER COSSLETT PUTNAM, M.S.

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A CHART SHOWING THE CHEMICAL RELATIONSHIPS IN THE MINERAL KINGDOM

THE PURPOSE OF THE CHART

The purpose of the chart is three-fold:

(A) To serve as a ready reference aid to the man who would know quickly, whether for an economic or a scientific purpose, the answer to such questions as: "How many and what are the minerals containing germanium, and what are their compositions?"; or, "Does silver occur with oxygen in any mineral?"; or, "Do phosphides or silicides occur as minerals?".

(B) To serve as an aid in Determinative Mineralogy, especially in the case of rare minerals, where either the small amount of the unknown substance, or the lack of laboratory facilities (as when in the field), precludes the possibility of making more than a few specific tests. It may also serve as a complement to microchemical methods in the laboratory, and as a reminder to verify the presence or absence of minute quantities of certain interesting replacing elements.^a

(C) To form a mechanical stimulus to speculation upon the chemistry of the earth, by affording upon one sheet a statistical survey of the affinities and the antipathies which hold sway in the mineral kingdom.

THE SCOPE OF THE CHART

(A) **The Elements**—The eighty-four major active elements are listed. The eight omitted include: three of the five inert noble gases, krypton, xenon and neon, known only in traces in the atmosphere; polonium and actinium, whose presence may be assumed whenever uranium is reported; the little known rare-earth, celtium; and two of the unknown elements, numbers 85 and 87, which quite possibly are mere transitional atomic configurations, whose stability is of a low order even in terms of actinium C. (Numbers 43 (eka-manganese), 61, and 75, elements as yet awaiting their discoverer, have been supplied with columns.)

The thirty or more known products of radio-active disintegration are not listed, but are assumed to be present whenever the respective parents of the three most important series are reported, and are included in the subscript "etc." to U, Th and Ra respectively. The latter, though but a stage in the U series, is so important as to justify its emphasis by specific mention.

^a See page 6, *et seq.*

The eight common inorganic radicals are listed.

The water molecule is listed.

Neodymium, (Nd), and praseodymium, (Pr), always occur together, and are inclusively symbolized by Di, the abbreviation for "didymium," their former joint name.

Save in the case of iron, no differentiation is made between the various valencies.

(B) **The Minerals.**—A mineral is here understood to be an aggregate of atoms whose physical state is the solid,^a whose crystallographic^b and optical constants vary within specific limits, whose chemical composition varies within specific limits, and which has been formed in nature under cosmic, atmospheric or telluric conditions of electro-chemical equilibrium.

All minerals described before July, 1924, in the literature mentioned under "References," are entered. This includes a number of sub-species, a number of doubtful species, many varieties based upon chemical composition, and the liquid, native mercury. Optical and crystallographic data, so far as possible, were the criteria of the individuality of a given mineral. The minerals are sixteen hundred and eleven in number.

THE MECHANICS OF THE CHART

(A) The Coördinates:

1. The right- and left-hand vertical margins; i.e., the termini of the horizontal columns.

Here is included:

- I. Each element, (and the ammonium radical), which occurs in nature as the *dominant electro-positive* constituent of a mineral. (Ca in calcite, CaCO_3).
- II. Each element which occurs uncombined, but in mineral form. (Pd in allopalladium, Pd.)

2. The top and bottom horizontal margins; i.e., the termini of the vertical columns:

Here are included:

- I. All the elements, (and the ammonium radical), occurring in nature in the *electro-positive* state, but as *minor* constituents of minerals. Since every active electro-positive element occurs in subordinate amount in at least one mineral, all are here entered.

^a Exceptions to this are the elements Hg, He, and A. Mercury is the sole constituent of the metallic liquid, native mercury; helium is a gaseous product of radio-active disintegration, found in many minerals; and the gas argon, also possibly a disintegration product, is known in a few minerals.

^b With the obvious exception of thirty or forty hardened colloid gels.

- II. Those elements occurring in nature as the *electro-negative* constituents of minerals, whether *dominantly or subordinately so.* (Te, dominant, S, subordinate, in sulfurous tetradyomite, Bi (Te, S)).
- III. The common electro-negative radicals.
- IV. The water molecule.
- V. Three of the unknown elements, entered by their atomic numbers.
- VI. A column designated "Nat. El," for the native elements.

In effect, then we have the *dominant electro-positive* elements plotted against *all* the *electro-positive* elements and *all* the *electro-negative* elements, and against the *common radicals.*

(B) **The Data:**

1. Each number refers to a mineral. The numbers are chosen arbitrarily, and are listed numerically in Index II.
2. The minerals are entered in the chart according to their composition. A hydrous neutral ferrous sulfate, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, (No. 536), is entered in the horizontal Fe'' column, in the SO_4 box and in the H_2O box. An aluminum silicate, Al_2SiO_5 , (No. 236), is entered, in the horizontal Al column, in the Si_xO_y box.
3. Complex minerals are entered as follows:

A mineral containing more than one electro-positive element, as a ferro-magnesian silicate, is entered in the horizontal column of the dominant electro-positive element; i.e., that one present in the greatest percentage weight. Should the analysis, (No. 1592), record 31% Fe'' and 32% Mg, the mineral would be entered in the horizontal Mg column, and would pick up Fe'' in the Fe'' box, and silica in the Si_xO_y box.

4. Certain oxygenated radicals, not specifically listed as coördinates, (the arsenates, antimonates, borates, tellurites, mellates, etc.), are indicated thus:

In the case of a ferric tellurite, Fe_2TeO_5 , (No. 1233), the mineral is entered in the horizontal Fe''' column, in the O box and in the Te box. In other words, if there is any oxygen in a mineral not accounted for in a specific radical, as the SO_4 or Si_xO_y radical, an entry is made in the O box of the appropriate horizontal column.

5. It will be noted that certain of the radicals are written with *x* and *y* as subscripts, in lieu of numerals. This is to indicate that

more than one acid is represented. Si_xO_y , for instance, indicates that SiO_2 is the salt of not merely H_2SiO_3 , but of one or more acids in addition.

THE ACCURACY OF THE CHART

The sources of error may be divided into three groups:

(A) Errors in original data.

1. Typographical.
2. Analytical.
 - I. Of omission.
 - II. Of commission.

(B) Errors in interpretation of original data.

(C) Mechanical errors in transcription of these data.

(A) Probable Errors in Original Data:

1. *Typographical.*

Although cross references were used, few typographical errors in analytical data were detected, and in most cases it could be determined which was the correct information.

2. *Analytical.*

These fall into two groups:

I. *Errors of Omission.*

The analyst either failed to weigh one or more oxides, as shown by the fact that his results fell short of 100 by an amount greater than his experimental error, or he unwittingly precipitated two or more oxides together, but weighed them as one, obtaining an apparently satisfactory analysis. Errors of the first type are not common, since the curiosity of the investigator usually did not permit the discrepancy to remain long a puzzle. Errors of the second type were fairly common prior to 1886, but after this date they were practically confined to two groups of elements, the radio-active and the rare-earth groups. It has been possible largely to correct for the errors of omission occurring in these two groups. The correction has been made as follows:

Radio-active Group: Whenever uranium was reported, the presence was assumed of radium and helium. The other fifteen or more products of disintegration were also

present, but are grouped under the subscripts "etc." Uranium lead was also undoubtedly present, but unless in quantity sufficient to be detected analytically, has not been reported, in order not to confuse the determinative work.

Whenever thorium was reported, the presence of the commercial mesothorium, along with the other ten or more products of this series, was assumed, and is indicated in the subscript "etc."

Rare-earth Group: Where the phrase " Ce_2O_3 etc." occurred in the analysis, it was assumed that all the elements of this group were present. Where the phrase " Yt_2O_3 etc." occurred, the same assumption was made for this group. Where oxides of one group only were reported, it was assumed that members of the other group were not present. This is not strictly so, since the two groups merge into one another through the medium of the Terbium group, and since scandium is known^a to occur, once at least, solely with the yttrium earths. Until more accurate analytical data are available, however, this assumption, in conjunction with the following classification^b of the elements, would appear to be the closest approximation to the truth:

<i>Cerium Group</i>		<i>Yttrium Group</i>	
Cerium	Ce	Celtium	Ct ^e ?
Europium	Eu ^c	Dysprosium	Dy
Gadolinium	Gd ^c	Erbium	Er
Lanthanum	La	Holmium	Ho
Neodymium	Nd ^d	Lutecium	Lu
Praseodymium	Pr ^d	Terbium	Tb ^c
Samarium	Sm	Thulium	Th
Scandium	Sc	Ytterbium	Yb
		Yttrium	Yt

^a Thortveitite, No. 813.

^b The author is not a student of rare-earth chemistry, and borrowed this classification from Browning's "Introduction to the Rarer Elements." The original articles containing the analyses were not consulted in most instances, and, had this been done, more satisfactory data might have been obtained.

^c These are sometimes grouped together as the Terbium group.

^d These two elements, before differentiation, were considered to be one element, "didymium." Since they invariably occur together, and to save space, they are here grouped together under their former symbol, (Di).

^e The recent discovery of hafnium, atomic number 72, has made the position of celtium obscure. The latter is known only spectroscopically, while some zircons contain 14% Hf.

II. *Errors of Commission*

Especially in certain of the older analyses, when mechanical methods of separation were not highly developed, products of alteration and adventitious material probably were present in a regrettably large amount. This error is large, indeterminate, but nearly negligible so far as the virtue of this chart is concerned, and has been partially rectified, as indicated in the next paragraph.

(B) Probable Errors in the Interpretation of Data:

It is hoped that the author's interpretation of doubtful data minimized rather than augmented the indigenous errors. When the chart was first made, in 1920, only those elements occurring in a formula as given in the standard works were included, and only about 900 minerals were plotted. When the chart was expanded to include all minerals described up to July, 1924, many of the replacing elements were included. The criteria of the legitimacy of the rôle played by a minor constituent were developed as follows:

An arbitrary distinction was made between two types of element, which we may designate the "aluminum" type and the "indium" type, respectively. To the former type belong such common elements as Na, K, Mg, Ca, Al, O, Fe'', Fe''' and, to a certain extent, Si, Ti and Mn. To the latter type belong such mineralogically rare and interesting elements as A, N, Li, Rb, Cs, Cd, Sc, Ga, In, Tl, Ge, Zr, Sn, Cr, Co and Ni, the isotopes of Pb, and the significant He.

A great many analyses, especially of non-metallies, show the presence of one or more of the *first* type in amounts ranging from a trace to two or three per cent. In general these quantities have been assumed to be adventitious and have been *disregarded* unless:

1. There is evidence that the analysis was of exceptionally pure material.

Example: (Rare.)

2. That the occurrence was consistent in a number of analyses from different localities.

Example: Small quantities of Ni in serpentine.

3. That the element was an isomorphous replacement of one with which it is often associated.

Example: Small quantities of Na in orthoclase.

Many of the second type, however, are only to be detected spectroscopically and their relationship to their host is not certain. In the case of A and He, they are certainly uncombined and in the gaseous state, yet their occurrence in minerals is so rare, and their significance so great, that they have been duly entered where recorded in the literature.

As for such elements as In and Ga, we note their wide diffusion in nature, (few spectrographs of minerals lack the In lines, for instance), and we also note their great reluctance to concentrate themselves into palpable organizations. But the important and interesting phenomenon is, that they are not promiscuous in their associations, but *do* concentrate themselves slightly in certain favored hosts. So whatever the rôle of indium within the atomic aggregation which we are pleased to call sphalerite, for instance, it has been duly entered as a minor constituent and thus with other similar elements, though perhaps only present spectroscopically.

The differentiation between minor elements actually entering into the chemical structure of the mineral, those that are adsorbed, those that are occluded, those that are inert, and yet owe their existence to some radioactive parent in the mineral, and those that are merely mechanically adventitious, was assuredly not complete, and is therefore a source of error of indeterminate magnitude.

A source of error of a different sort is the differentiation between O, H, OH, and H_2O . The significance of H and OH is, except in certain obvious cases, purely academic. A complex formula is often written as an algebraic expression, with no indication of molecular structure. When the term "basic" is then applied to such a formula, it is not clear whether it is the oxygen ratio in the acid from which the given salt was derived which is referred to, or the actual presence of the OH radical. The term "acid" leads to the same confusion. And in many cases (*cf.* the zeolites), the structure is still a matter for discussion. In general, entries have been made in the H_2O column when water is lost below a red heat, and in the O and OH columns when lost only above a red heat. Entries have been made in the H column when the water given off, (below a red heat), is acid and in the OH column when basic, in addition to the entry in the H_2O column.

(C) Probable Mechanical Errors in Transcription of Data:

Errors from this source are largely due to astigmatism; to the entry of a number in a box immediately contiguous to the proper box. The chart was checked back to original sources in part six times, in part four times and, in part, only twice. Each one of these checkings revealed errors, progressively fewer. It is believed that the error due to this source is not greater than about 0.1%,

and probably less. This amounts to not more than ten individual entries. Further, it is an error usually quite obvious.

Recapitulation.

It is believed that the chart fairly faithfully represents the author's interpretation of the data in the literature; that errors of omission in a few of the older analyses are fairly common; that these latter have in part been corrected in the chart; that errors of commission were somewhat more common in certain of the older analyses; that the corrections of this type of error were probably not so effective as of the former type; that the greatest source of error, therefore, lies in this type of analysis and in the author's interpretation of it. The total percentage error is undoubtedly greater than it will be after a revision, but it is thought that its present accuracy is such that the chart may begin to function.

THE USES OF THE CHART

These are indicated on p. 1, and are largely self-explanatory, yet a few examples might not be amiss.

(A) The chart serves the first purpose as follows:

Example 1.—It is desired to know the occurrence of germanium, and its associations. Inspection of the right-hand margin reveals that Ge is not known to occur as a *dominant electro-positive* constituent of a mineral, and therefore occurs always as an accessory. Turning, then, to the vertical column headed by Ge, one thumbs down the chart and notes that the following minerals *always* or *usually* contain Ge:

- In the Ag^a box, numbers 55, 146;
- In the Cu box, number 1291;
- In the Fe" box, numbers 208, 795;
- In the Pb box, number 1116;
- In the Sn box, number 157;
- In the Yt box, numbers 297, 306, 327, 717;
- In the Zn box, number 764.

Turning to the numerical index, these numbers are found to refer respectively to:

Argyrodite, (55)	Cassiterite, (157)
Canfieldite (146)	Euxenite, (297)
Germanite, (1291)	Fergusonite, (306)
Columbite, (208)	Gadolinite, (327)
Tantalite, (795)	Samarskite, (717)
Ultrabasite, (1116)	Sphalerite, (764)

^aA line under a chemical symbol indicates that it is the horizontal column of that element which is referred to, and not its vertical column, in which case there is no underline.

To find the complete composition of each of these, including other rare constituents not usually recorded in mineralogical texts, inspect to the right and left of each number for further entries. This is facilitated by the arrangement of all the numbers of a given box in numerical order. Thus 55, for instance, is found to appear only in the S box, in addition to its entry in the Ge box. Since these entries are in the Ag horizontal column, it follows that argyrodite is a silver germanium sulphide, the silver dominating the germanium in percentage weight.

Example 2.—What minerals, if any, contain thallium as a major constituent? Inspection of the right-hand margin shows that Tl does form the dominant electro-positive constituent of some minerals, and running along this horizontal column we find:

- In the Ag box, number 912;
- In the As box, numbers 508, 866, 912;
- In the Pb box, number 912;
- In the S box, numbers 508, 866, 912;
- In the Sb box, number 866.

In the numerical index, these numbers refer to:

- Lorandite, (508)
- Vrbaite, (866)
- Hutchinsonite, (912).

If information is desired concerning the occurrence of Tl as an accessory constituent, one proceeds as with Ge and finds that:

- In the Al box, numbers 26, 487;
- In the Au box, number 787;
- In the Cu box, numbers 98, 175, 226;
- In the Fe" box, numbers 523, 672;
- In the Fe"" box, number 388;
- In the K box, number 149;
- In the Mn box, number 125;
- In the Zn box, number 764;

have been reported to carry traces or more of Tl.

In the numerical index, these numbers refer to:

- | | |
|---------------------|-------------------|
| Alunite, (26) | Marcasite, (523) |
| Lepidolite, (487) | Pyrite, (672) |
| Sylvanite, (787) | Hematite, (388) |
| Berzelianite, (98) | Carnallite, (149) |
| Chalcopyrite, (175) | Braunite, (125) |
| Crookesite, (226) | Sphalerite, (764) |

(B) The use of the chart as an aid to Determinative Mineralogy is illustrated by the following two examples:

Example 1.—A minute quantity of a yellow, earthy incrustation on barite was to be tested. A fine closed-tube test was run. Vapours of iodine, and possibly of other halogens, were given off. Inspection showed:

<u>Ag</u> box	431 Iodobromite
	432 Iodyrite
	555 Miersite
<u>Ca</u> box	258 Dietzite
	1393 Lautarite
<u>Cu</u> box	1437 Marshite
<u>Pb</u> box	732 Schwartembergite

to be the iodides occurring in nature. A reference to a descriptive text often will give physical data which may aid in eliminating some of these minerals, and thus further reducing the number of microchemical or blow-pipe tests required to determine the mineral or to suggest that it is a mixture or a new species. In the case under discussion, the physical data were inconclusive. In order to prove the unknown to be one of these iodides, tests had to be run for Ag, Cu, Ca and Pb. The tip of the C. T. was pulverized and introduced into a three-inch test-tube. Warmed with a few drops of 6N-HNO₃, the assay went completely into solution with no effervescence. Addition of NH₄OH produced no ppt. nor the formation of a distinctive colour. The NH₄OH was gently expelled and some (NH₄)₂C₂O₄ added. No CaC₂O₄ was formed. A few drops of HCl were added, and no ppt. formed immediately, suggesting the absence of Ag. After six hours' standing, a fine white ppt. formed. Upon heating, it went back into solution, ruling out AgCl, but, in the cold, it recrystallized. Under the glass the crystals were seen to be fine prismatic needles, with adamantine luster, and were presumably PbCl₂. Thus schwartembergite was indicated qualitatively, and later checked optically.

Example 2.—During the course of a preliminary geological survey of Uganda¹⁴, Wayland and his assistants had occasion to determine a mineral occurring in and on fossilized wood from the Mount Elgon (Pliocene?), volcanic series. Their laboratory facilities being scanty, they were able to make only limited qualitative tests.

" . . . , but the behaviour of the acicular mineral associated with the wood seems to indicate that it must be a true mineral substance and not a mixture.

"Some of the patches of acicular crystals are pure white but mostly they are a dirty yellowish colour. They occur in tufts thickly covering the cavities and rest on a massive incrustation of the same composition. . . . In cold dilute HCl they are only slightly acted upon, but on warming, they are soluble with effervescence of CO₂. On putting aside after five or six hours the whole solution sets to a jelly. . . . On heating in the closed tube the crystals become opaque, transparent ones becoming white and the yellowish ones becoming black. Water is evolved and this water vapour when it condenses on the tube gives an alkaline reaction with litmus paper. Heated in a tube with lime, ammonia is evolved and a good alkaline reaction is obtained. In the blowpipe the crystals are fusible at the ends to an enamel. With fusion mixture (*sic*) on charcoal and then cobalt nitrate a strong blue aluminum colour ^a is given. A flame test for calcium could not be obtained. The tests above given show the presence of Aluminum, ^a Ammonium, a Carbonate and Silicate, with hydroxyl, and the mineral species to which such a compound can be referred is doubtful. . . . It is not clear that a hydrous silicate can enter into combination with a carbonate."

These data applied to the chart, yield the following results in two or three minutes:

1. There are six hydrous silicates known to contain carbonate:

<u>Al</u>	1037	Cancerinitite
	1038	Sulfatic cancerinitite
	1214	Davyne
<u>Ca</u>	806	Thaumasite
	1539	Plazolite
<u>Yt</u>	164	Cenosite

2. Though these hydrous silicates contain carbonate, no one of them contains ammonium.

3. Ammonium occurs with water, but not in the presence of hydroxyl, carbonate, or silicate.

4. Ammonium occurs with carbonate, but not in the presence of silica, water, or hydroxyl.

Thus, were the "acicular mineral," (as tested), truly homogeneous, it would be a new mineral; but it would not only be a new mineral; it would represent a new chemical type; and not only one new type, but three new types! The probability that the material tested was a mixture is thus strongly emphasized.

^aMost fusible or fluxed silicates and many other fusible minerals give a good blue colour when heated with Co(NG₃)₂, in addition to those infusible numerals whose blue colour is a specific test for aluminum compounds or the zinc silicates.

(C) The mechanical presentation upon one sheet of the affinities and antipathies which hold sway in the mineral kingdom is instructive, and aids in emphasizing many interesting inter-relationships which it might prove difficult to grasp in another way.

The array of numbers in the $\text{Al Si}_x\text{O}_y$ box, for instance, emphasizes visually the importance of such minerals in the scheme of things. The great affinity of Ca for Al in the presence of Si_xO_y is brought out, as also the even greater (statistical) affinity of Na for Al under the same conditions.

Many other suggestive relationships among less common elements are indicated. There is no need of enumerating them here.

These relationships are only crudely quantitative, since the entries were made by percentage weight, and not by molecular proportions, and since the individual minerals have not been weighted according to their occurrence in the earth's crust.

Further, this method of presentation serves to emphasize in a clearcut manner the distinction between elements of the "indium" type, which, above a certain low saturation point, prefer the company of others to that of themselves, and those of the "aluminum" type, which show greater development of the herd instinct, for, when present at all, they are usually present in large quantities.

NOTICE OF A DETERMINATIVE SCHEME

It is obvious that a *determinative scheme*, embracing the mineral kingdom, and developed on the plan of successively testing for specific elements, by blowpipe and wet chemical methods, would be the logical complement to this chart. Such a scheme was indeed developed during the winter and spring of 1920, for use by the author in the elementary course of mineralogy given by Dr. Warren at the Massachusetts Institute of Technology. It included about 350 of the common minerals. In the summer of 1920, it was made to include about 900 minerals, and in 1923 was submitted as partial fulfilment of the requirements for the degree of Bachelor of Science. It has since been in use by the author, in the laboratories of the Department of Geology at the Institute, and in 1924 was tested out under the supervision of Dr. Lindgren. It is now being further revised, and expanded so as to include all minerals. Some refinements in the specific tests for elements are being tried out, and it is hoped to bring the entire scheme to completion within a year.

BINGHAM CANYON,
Aug. 23, 1924.

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1433. Manganpectolite	1501. Palmierite	1569. Rathite
1434. Mangan-vesuvianite	1502. Tourmaline, magnesian	1570. Redingtonite
1435. Mansjöite	1503. Paracoquimbite	1571. Rhodolite
1436. Marmatite	1504. Paraurchalcite	1572. Rhombooclase
1437. Marshite	1505. Paralaurionite	1573. Rhönite
1438. Marsjatskite	1506. Paraluminite	1574. Richellite
1439. Martite	1507. Paramelaconite	1575. Brandisite
1440. Maskelynite	1508. Parasepiolite	1576. Riversideite
1441. Mauzeliite	1509. Paravivianite	1577. Romeite
1442. Mazapilitite	1510. Paravauxite	1578. Rosasite
1443. Melanovanadite	1511. Paredrite	1579. Roschérite

1580. Rosenbuschite	1598. Mariposite	1615. Rhodocrosite, calciferous
1581. Rothoffite	1599.	1616. cobaltiferous
1582. Rowlandite	1600. Yttrocrasite	1617. Sarcopside
1583.	1601. Heterogenite	1618. Magnesiochromite
1584. Tengerite	1602. Wattevellite	1619. Schorlite
1585. Joaquinite	1603. Volchonskoite	1620. Schroecckingerite
1586. Corkite	1604. Uranochalcite	1621. Rhodocrosite, magnesic
1587. Parisite	1605. Pleonaste	1622. Stevensite
1588. Ruby, oriental	1606. Iron - copper - chalcan-	1623. Monimolite, calciferous
1589. Emerald, oriental	thite	1624. Tarapacaite
1590. Amethyst, oriental	1607. Heubachite	1625. Tamarugite
1591. Chlorospinel	1608. Wodanite	1626. Titanolivine
1592. Hyalosiderite	1609. Barytbiotite	1627. Silver, auriferous
1593. Pseudomesolite	1610. Löllingite, cobaltiferous	1628. Hydrotroilite
1594. Soda-sarcolite, an hypo-	1611. Trerorite	1629. Gel-cerargyrite
thet. mol	1612. Plumboferrite	1630. Hydrocuprite
1595. Zebedassite	1613. Vauxite	1631. Gel-variscite
1596. Xonotlite	1614. Cornetite	1632. Spheromangite
1597. Destinezite		

BLANK NUMBERS

The following numbers had been assigned to minerals which were later, for one reason or another, stricken from the chart. They *do not now* appear upon the chart, and appear in the Numerical Index followed by a blank.

271, 309, 433, 534, 958, 1041, 1055, 1088, 1237, 1254, 1265, 1273, 1350, 1398, 1460, 1471, 1522, 1564, 1567, 1583, 1599.

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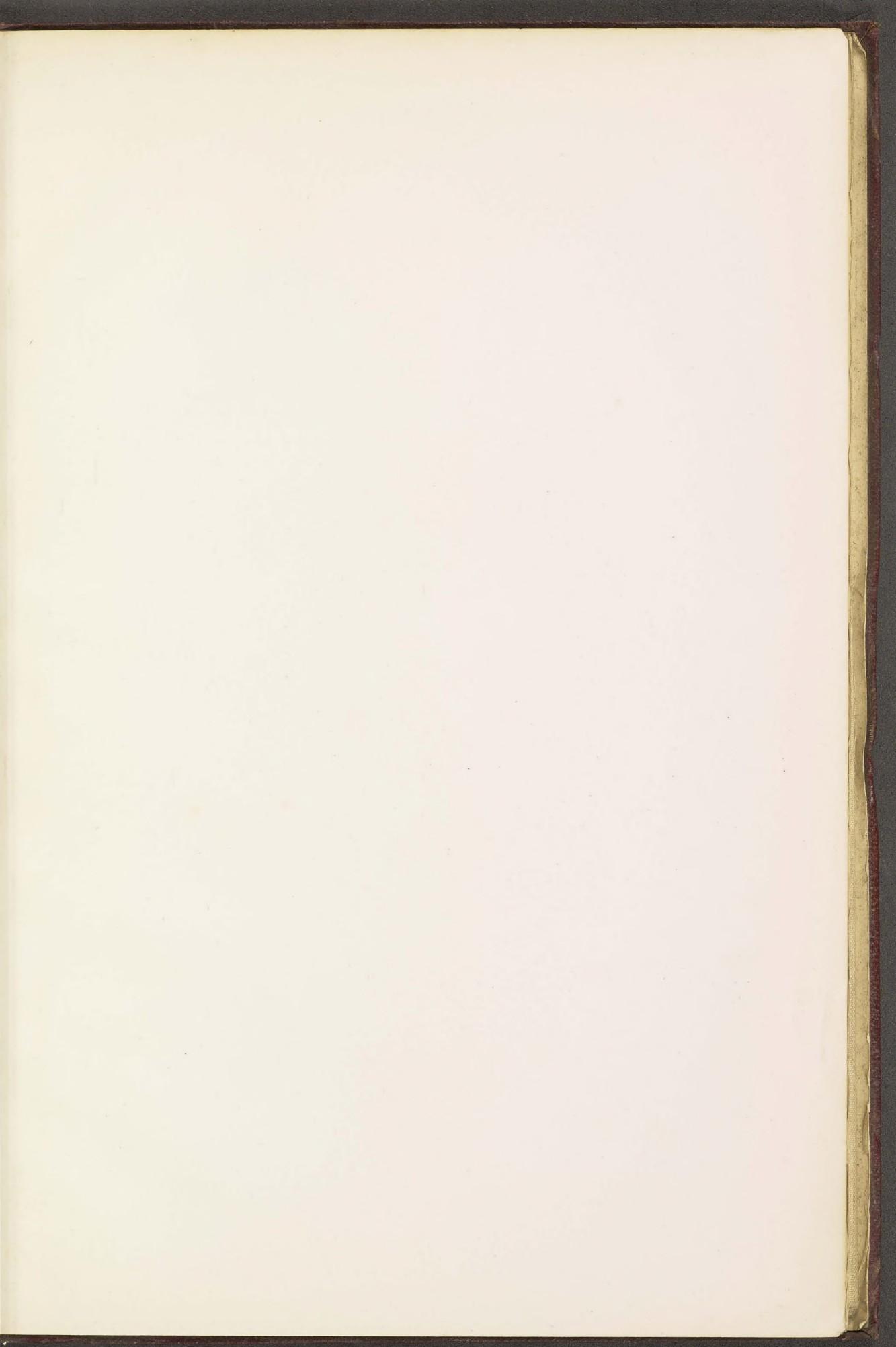
22

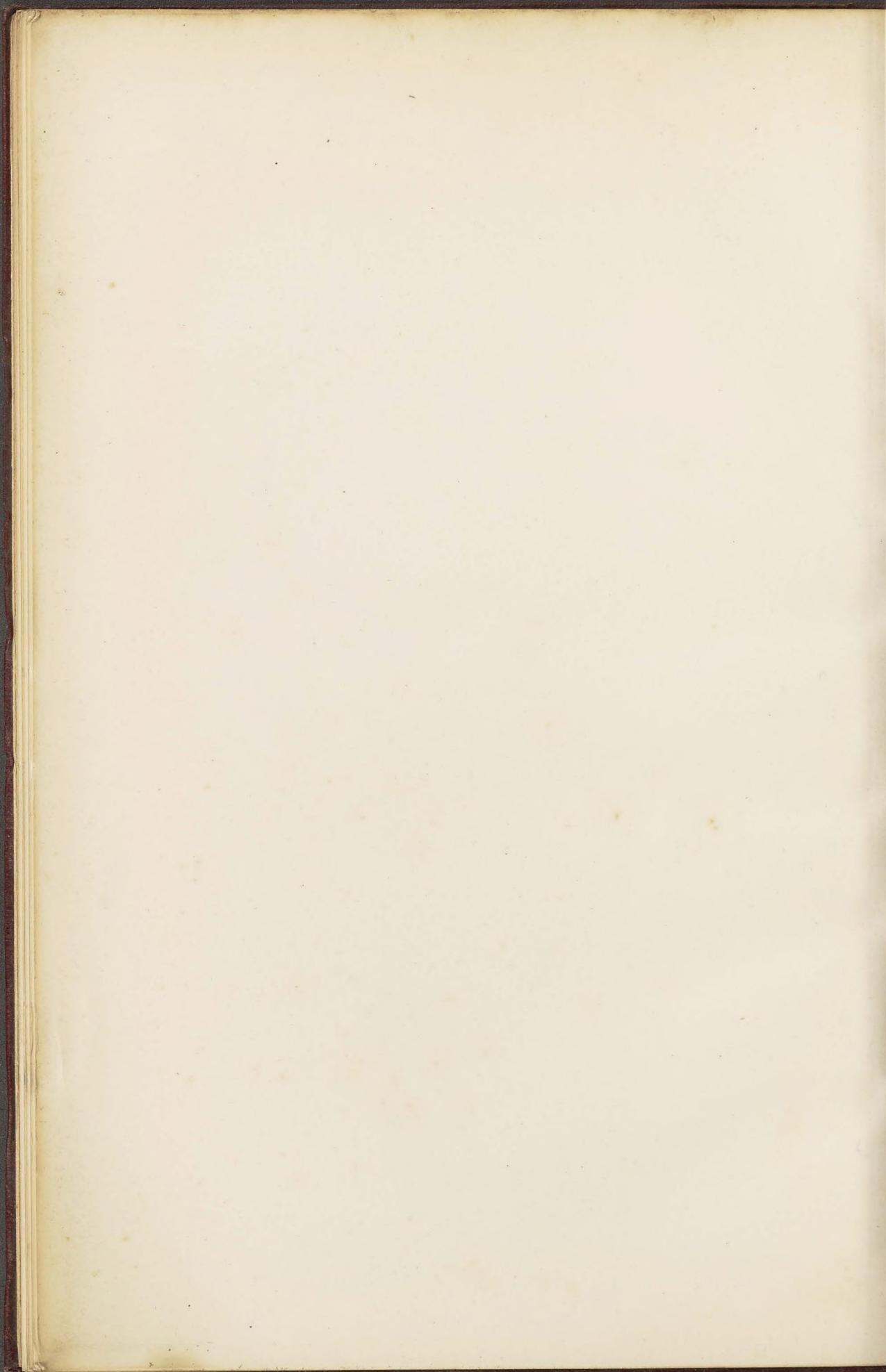
23

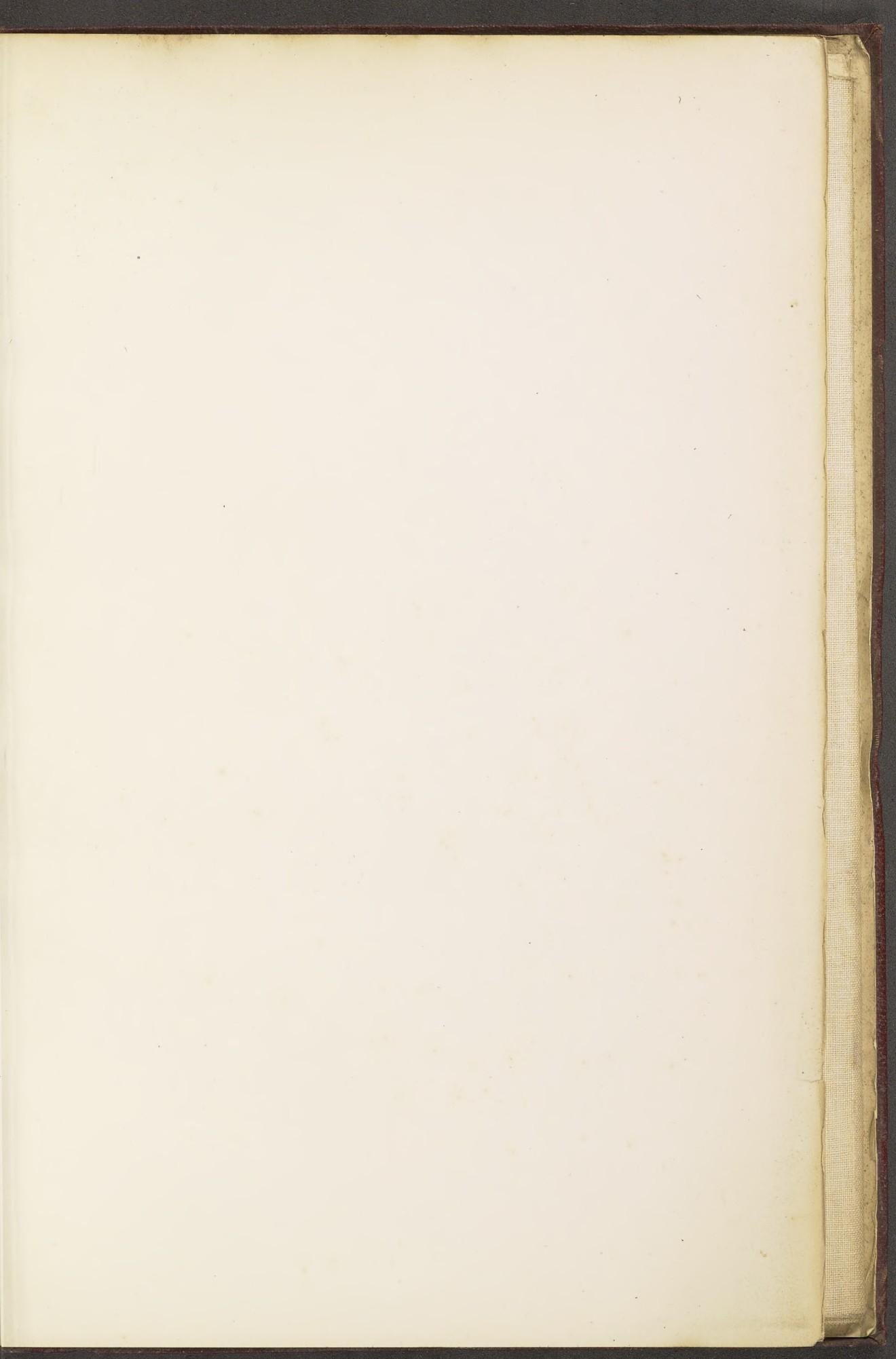
24

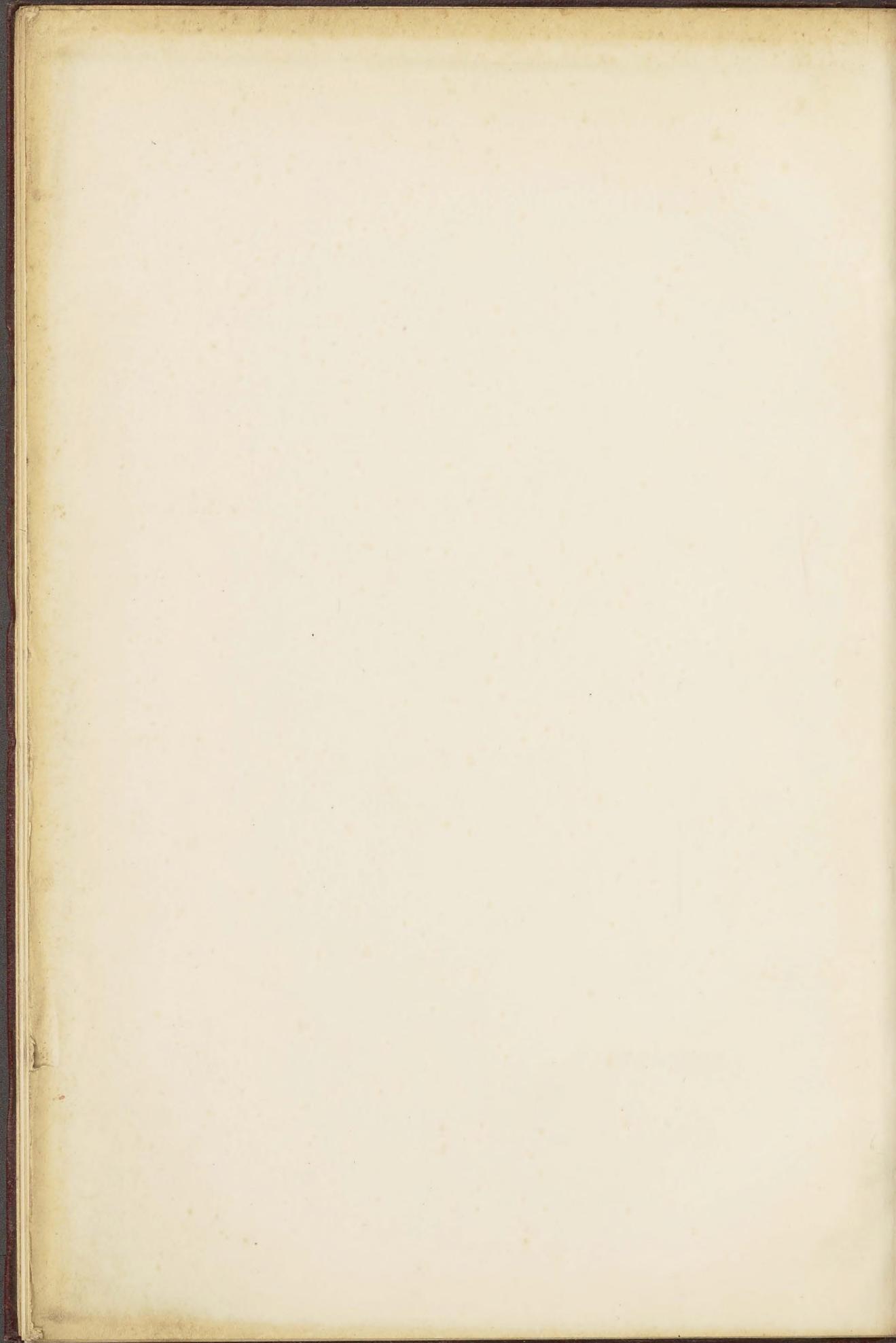
25

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RELATIONSHIPS IN THE MINERAL KINGDOM

